## PROGRESSIVE MULTIFOCAL OPHTHALMIC **LENSES**

## BACKGROUND OF THE INVENTION

The present invention is generally directed to ophthalmic lenses and, in particular, to progressive multifocal ophthalmic lenses which include a far vision viewing zone, a near vision viewing zone and an intermediate zone which smoothly blends the far vision viewing zone into the near vision viewing zone.

Each of the different viewing zones in progressive multifocal ophthalmic lenses are of different power for properly viewing objects at different distances. The refractive surface of such lenses are aspherical which inevitably causes a large amount of astigmatism and distortion. Accordingly, attempts have been made to design the refractive surface of such lenses in order to improve the characteristics thereof and reduce the astigmatism and distortion. U.S. Pat. Nos. 3,687,528, 3,910,691 and 4,056,311 disclose various constructions for progressive multifocal ophthalmic lenses. Moreover, the present inventor has also invented several previous constructions for progressive multifocal ophthalmic lenses which are disclosed in co-pending U.S. 25 patent application Ser. No. 327,288, filed Dec. 3, 1981 now U.S. Pat. No. 4,580,883.

Lenses of the type described above are constructed to improve the curved lens surface in respective regions of the lens. However, zone of these lenses or the patents in 30 which they are described recognize that it is important in designing lenses to consider the optical efficiency and appearance of the lens, that is, considering a base curve (a curve of a refractive surface in the far vision viewing zone on the basis of which the curved surfaces in other 35 zones are determined) and the prescribed power. If the base curve and prescribed power are not in satisfying condition with respect to each other, the appearance of the lens is less than completely satisfactory and, also, in the case where a lens of strong power is prescribed, the 40 optical efficiency of the lens is deteriorated.

The present invention is directed to improved progressive multifocal ophthalmic lenses wherein the problems discussed above are substantially overcome or eliminated.

## SUMMARY OF THE INVENTION

Generally speaking, in accordance with the present invention, a progresssive multi-focal ophthalmic lens is provided. The lens includes a refractive surface divided 50 into a far vision viewing zone, an intermediate vision viewing zone and a near vision viewing zone. The refractive surface defines a substantially vertical principal meridian curve. An optical center of the far vision viewing zone is at the lower end of the principal merid- 55 ian curve in the far vision viewing zone and an optical center of the near vision viewing zone is at the upper end of the principal meridian curve in the near vision viewing zone. The curvature of the principal meridian curve changes between the optical center of the far 60 vision viewing zone and the optical center of the near vision viewing zone in accordance with a prescribed law to define the additional power of the lens. At each point on the principal meridian curve in at least one of the far vision viewing zone and near vision viewing 65 invention and the conventional lens, respectively; zone, the difference between the curvature along the principal meridian curve and the curvature along the vertical direction with respect to the principal meridian

curve at each point on the principal meridian curve is not zero in any part of the at least one zone.

Accordingly, it is an object of the present invention to provide an improved progressive multifocal ophthalmic lens.

Another object of the present invention is to provide a progressive multifocal ophthalmic lens in which astigmatism and image distortion in the far and near vision viewing zones are reduced.

A further object of the present invention is to provide a progressive multifocal ophthalmic lens which is thinner and lighter than conventional lenses.

A still further object of the present invention is to provide an improved progressive multifocal ophthalmic lens in which vision is improved in the near and far vision viewing zones with respect to astigmatism and distortion.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view showing the structure of a refractive surface of a progressive multifocal lens;

FIGS. 2 and 3 illustrate the distribution of astigmatism and the distortion of a progressive multifocal lens, respectively;

FIGS. 4A, 4B, 5A and 5B show the property of the conventional progressive multifocal lens in which the prescribed power of the lens and the base curve thereof is in a suitable condition and those in an unsuitable condition, respectively. FIGS. 4A and 5A illustrate the distribution of astigmatism and FIGS. 4B and 5B illustrate the focal power at each point on the principal meridian curve into the parallel and the vertical directions with respect to the principal meridian curve;

FIGS. 6A and 6B illustrate the change of the curvature at each point on the principal meridian curve into the parallel and vertical directions with respect to the principal meridian curve. FIG. 6A shows the change of curvature of the progressive multifocal lens according to the present invention and FIG. 6B shows the change of a conventional lens;

FIGS. 7A and 7B illustrate the change of curvature of the intersections vertical to the principal meridian curve in the far zone. FIG. 7A shows the change of the lens according to the present invention and FIG. 7B shows the change of a conventional lens.

FIGS. 8A and 8B illustrate the distribution of the astigmatism and the focal power at each point along the principal meridian curve of a lens according to a first embodiment of the present invention.

FIGS. 9a and 9B illustrate the astigmatism due to the aspherical surface of the convex side of a lens showing the difference between the lens according to the present

FIG. 10 illustrate the astigmatism due to the unsuitable condition of the base curve and the prescribed power of the lens;